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Cost of POU vs Centralized Treatment

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Overview

Contaminants to cover

Nitrate / Perchlorate

1) Anion exchange resin
2) Biological treatment (anoxic)
3) POU reverse osmosis membranes

Per- and Polyfluoroalkyl Substances (PFAS)

1) Activated carbon
2) Anion exchange resin
3) POU reverse osmosis membranes

Treatment Information

Publicly Available Drinking-Water Treatability Database

- Interactive literature review database that contains over 88 regulated and unregulated contaminants and covers 34 treatment processes commonly employed or known to be effective (thousands of sources assembled on one site)

Currently available:

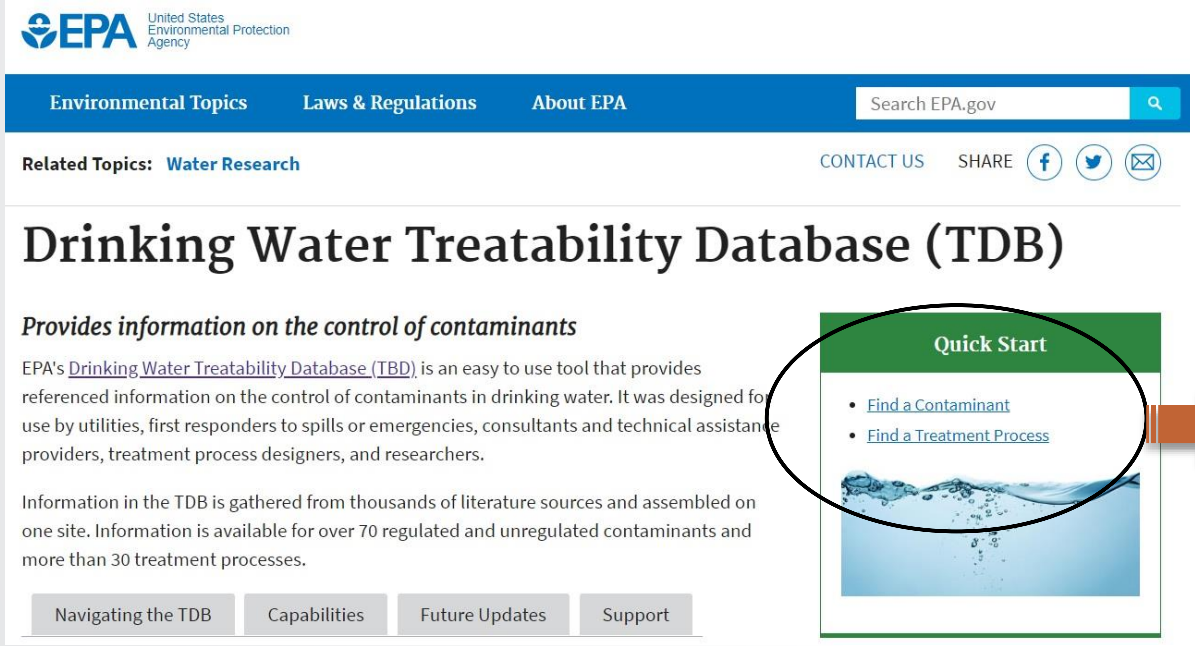
- **Nitrate**
- **Perchlorate**
- **PFOA, PFOS, PFTriA, PFDoA, PFUnA, PFDA, PFNA, PFHpA, PFHxA, PFPeA, PFBA, PFDS, PFHpS, PFHxS, PFBA, PFBS, PFOSA, FtS 8:2, FtS 6:2, N-EtFOSAA, N-MeFOSAA, and GenX**

https://www.epa.gov/water-research/drinking-water-treatability-database-tdb

Search: EPA TDB

Treatability Database

Agency Landing Page



Database Homepage

https://www.epa.gov/water-research/drinking-water-treatability-database-tdb

Search: EPA TDB

EPA's Drinking Water Cost Models

- Adsorptive media
- **Anion exchange (IEX) ***
- **Biological treatment***
- Cation exchange
- **GAC***
- Greensand filtration
- Microfiltration / ultrafiltration
- Multi-stage bubble aeration*

- Non-treatment
- Packed tower aeration
- **POU/POE#**
- Reverse Osmosis / Nanofiltration
- UV disinfection
- UV Advanced Oxidation

IEX and POU (nitrate, perchlorate, and PFAS), Biological treatment (nitrate and perchlorate), GAC (PFAS)

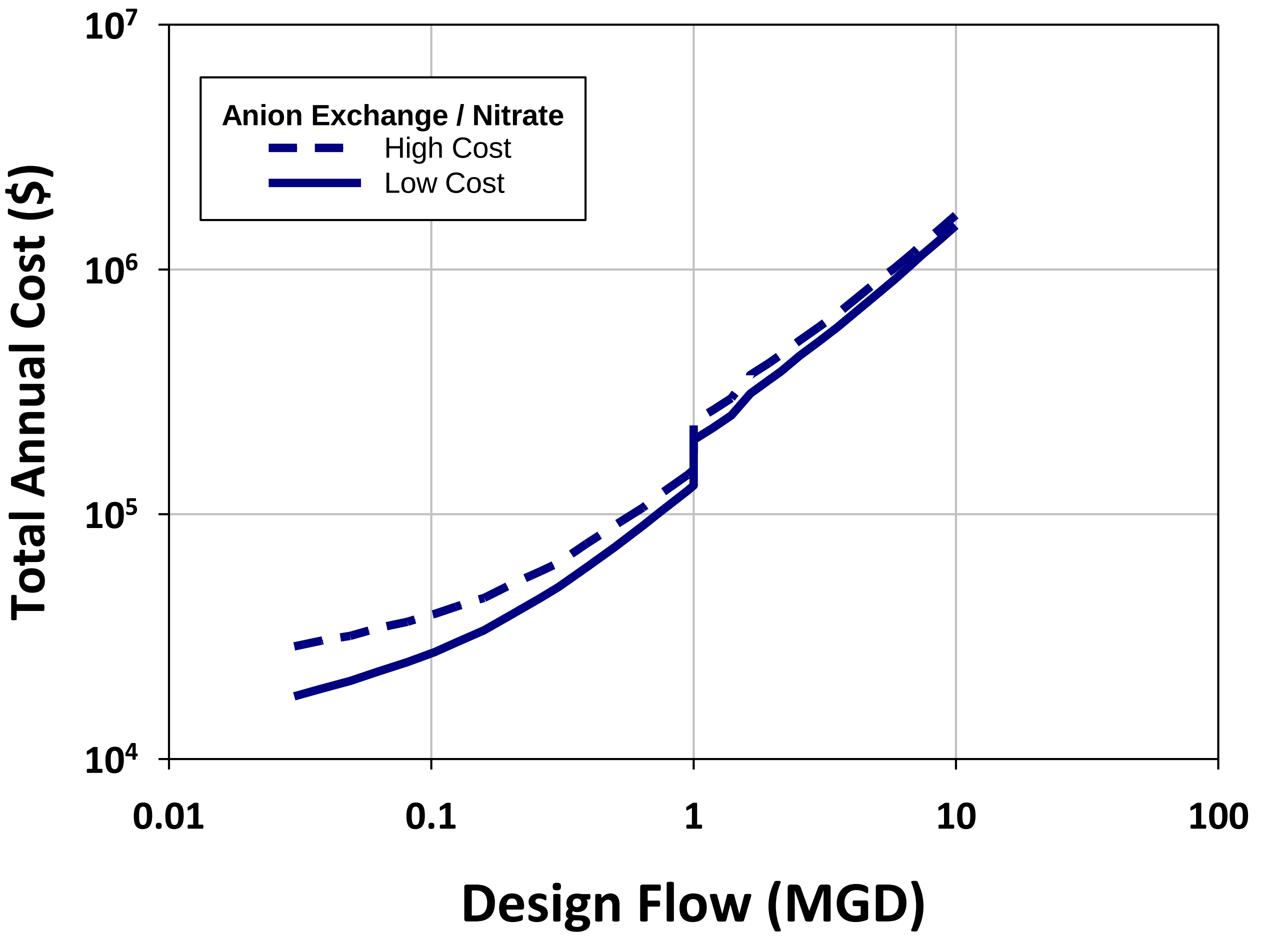
*** Search: EPA WBS** http://www2.epa.gov/dwregdev/drinking-water-treatment-technology-unit-cost-models-and-overview-technologies

 # For POU/POE: Temporarily taken off web: Please contact Rajiv Khera at Khera.Rajiv@epa.gov

Why Nitrate and Perchlorate?

- Nitrate: A number of utilities exceed the Maximum Contaminant Level (MCL), particularly small systems
- Perchlorate: State regulations and federal proposal
- Both are fully oxidized – oxidation processes including aerobic biotreatment will not work
- The treatment processes that will work are pretty much the same
  - Anion exchange resin
  - High pressure membranes: reverse osmosis or nanofiltration
  - Anoxic biological treatment (novel technology)

Cost: Nitrate / Anion Exchange

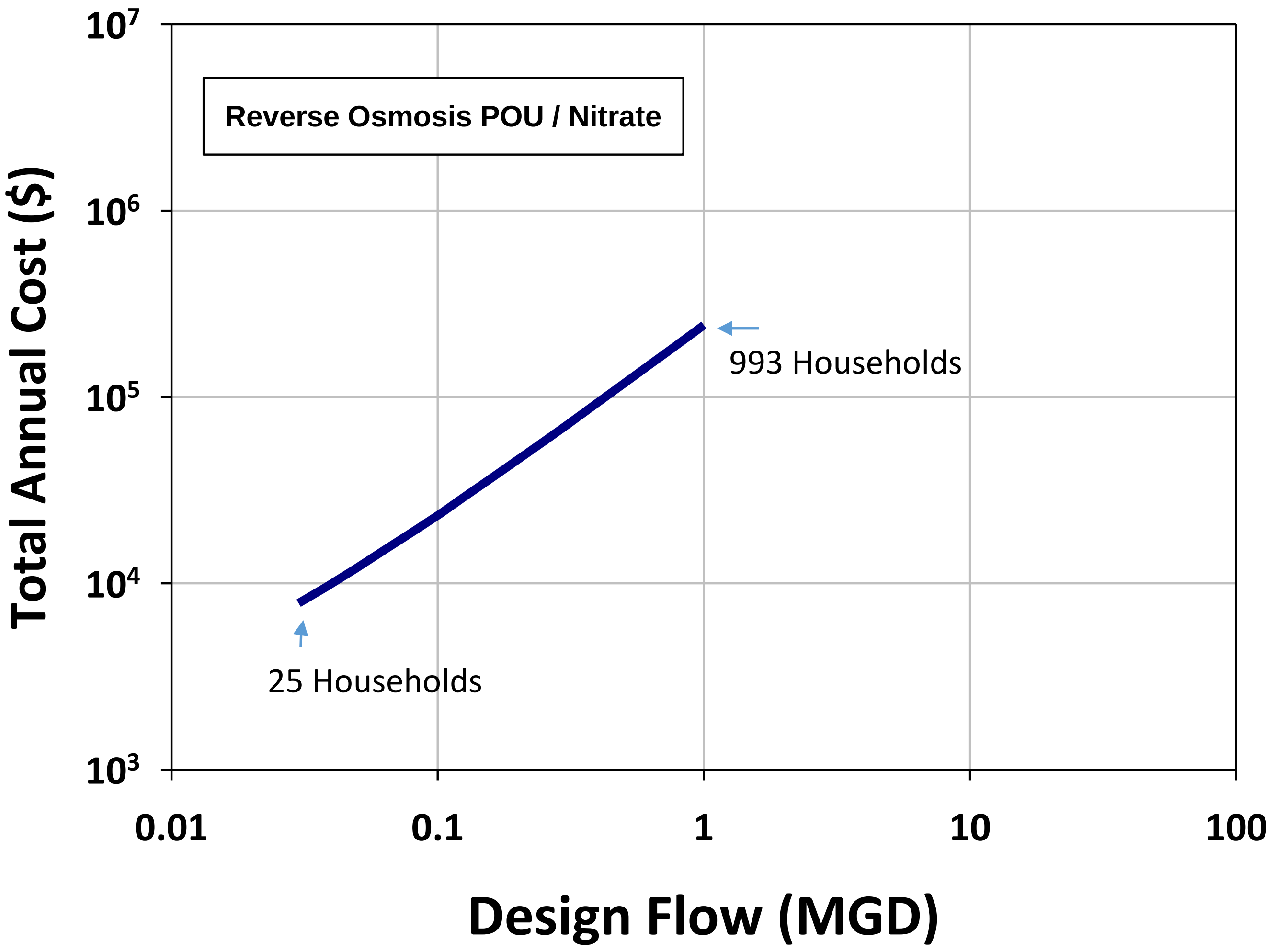


Primary Assumptions

- 20.3 mg N/L Influent
- Nitrate selective resin
- 420 bed volumes before regeneration
- 2 minute EBCT
- Parallel contactors
- Brine discharge to POTW

Cost: Nitrate / Point of Use

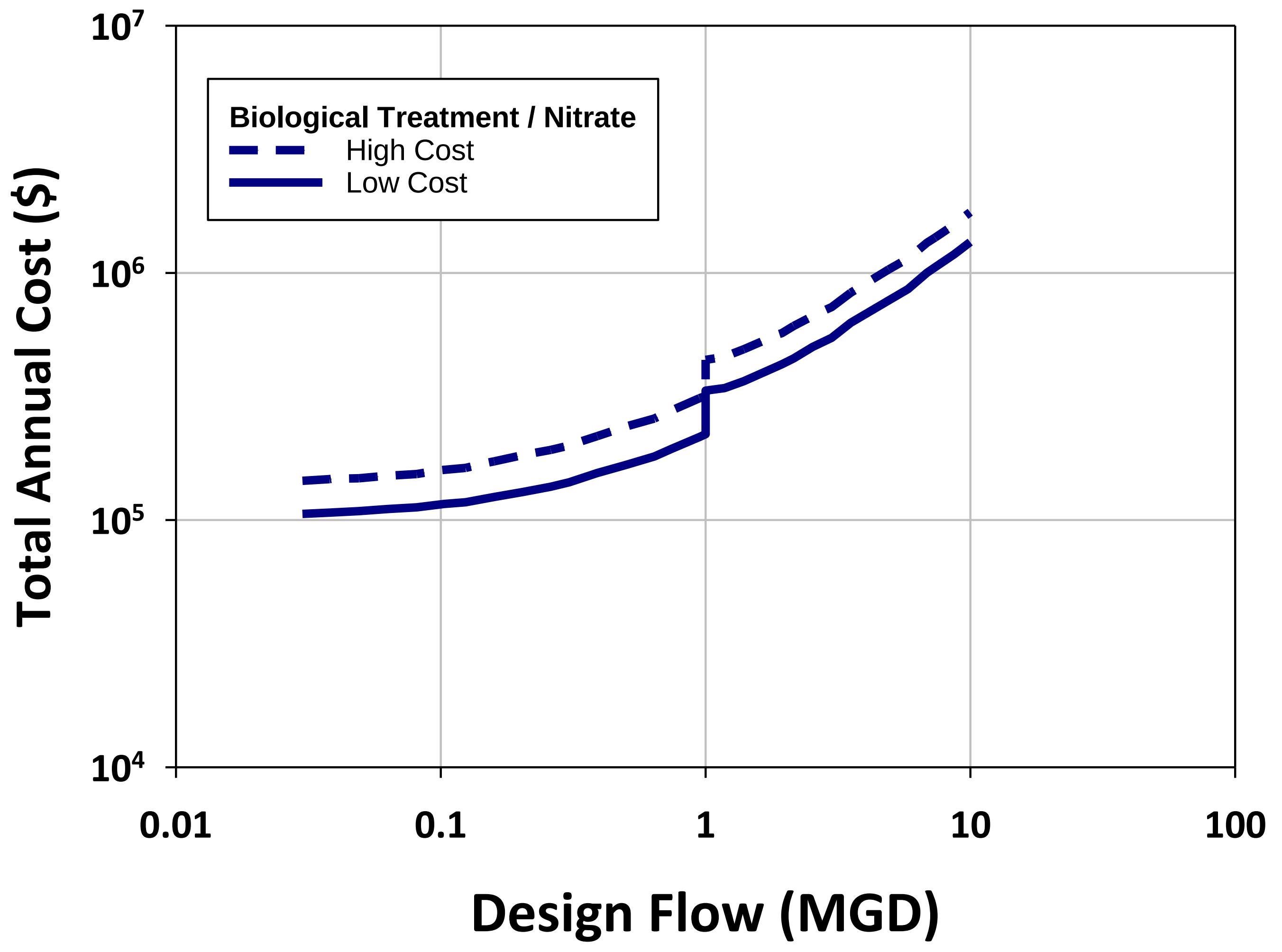
Only for 1 MGD design flow and below



Primary Assumptions

- 20.3 mg N/L Influent
- Reverse osmosis treatment
- Replacement frequency:
  - RO membrane: 3 years
  - Pre filters: 9 months
  - Post filter: 12 months
- Groundwater
- No post UV disinfection

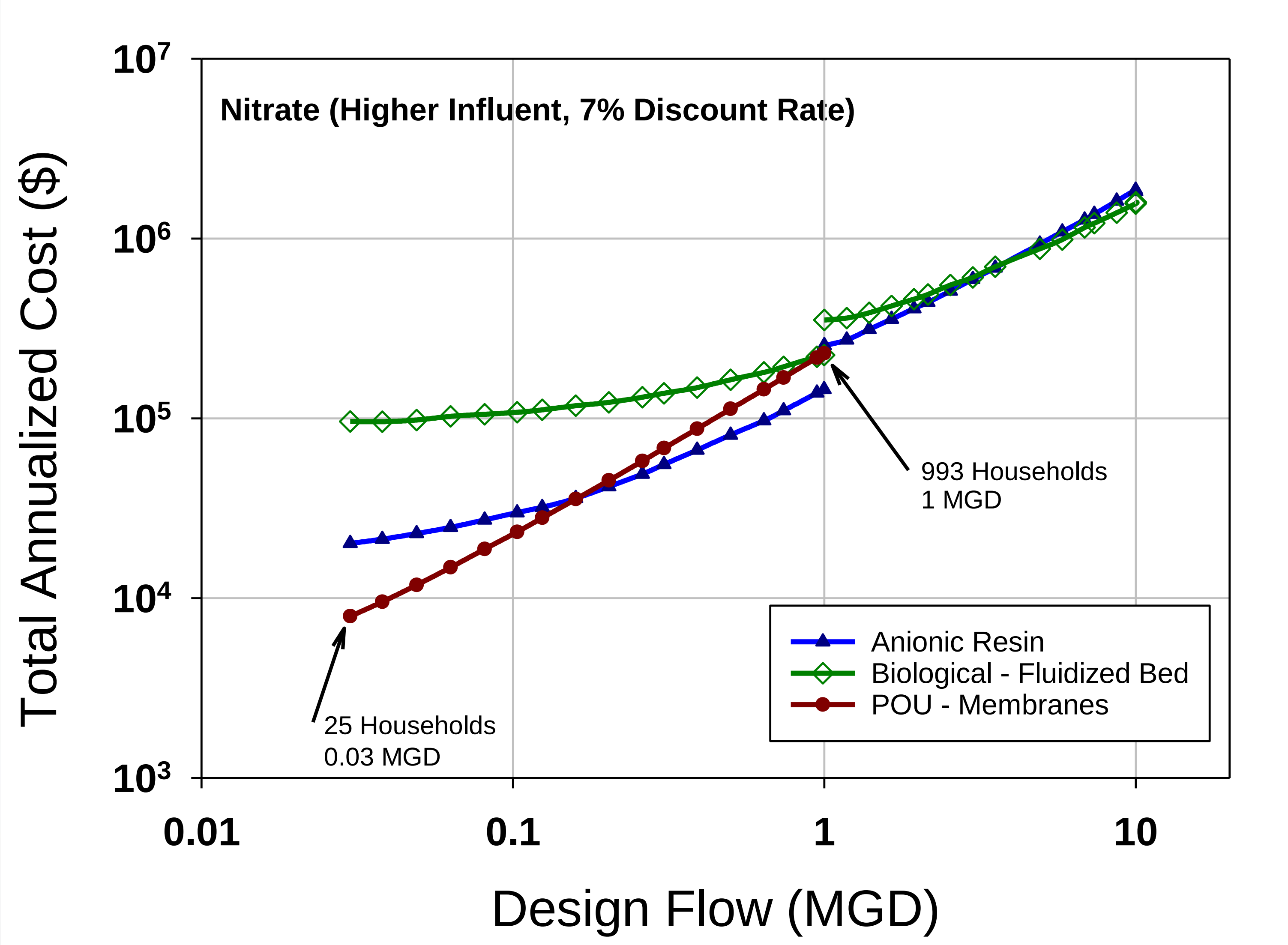
Cost: Nitrate / Anoxic Biological Treatment



Primary Assumptions

- 20.3 mg N/L
- Fluidized bed reactor
- 28.5 mg/L acetic acid
- 2 mg P/L phosphoric acid
- 10 minute EBCT
- Post treatment aeration
- Post treatment filtration
- Recycle of spent backwash

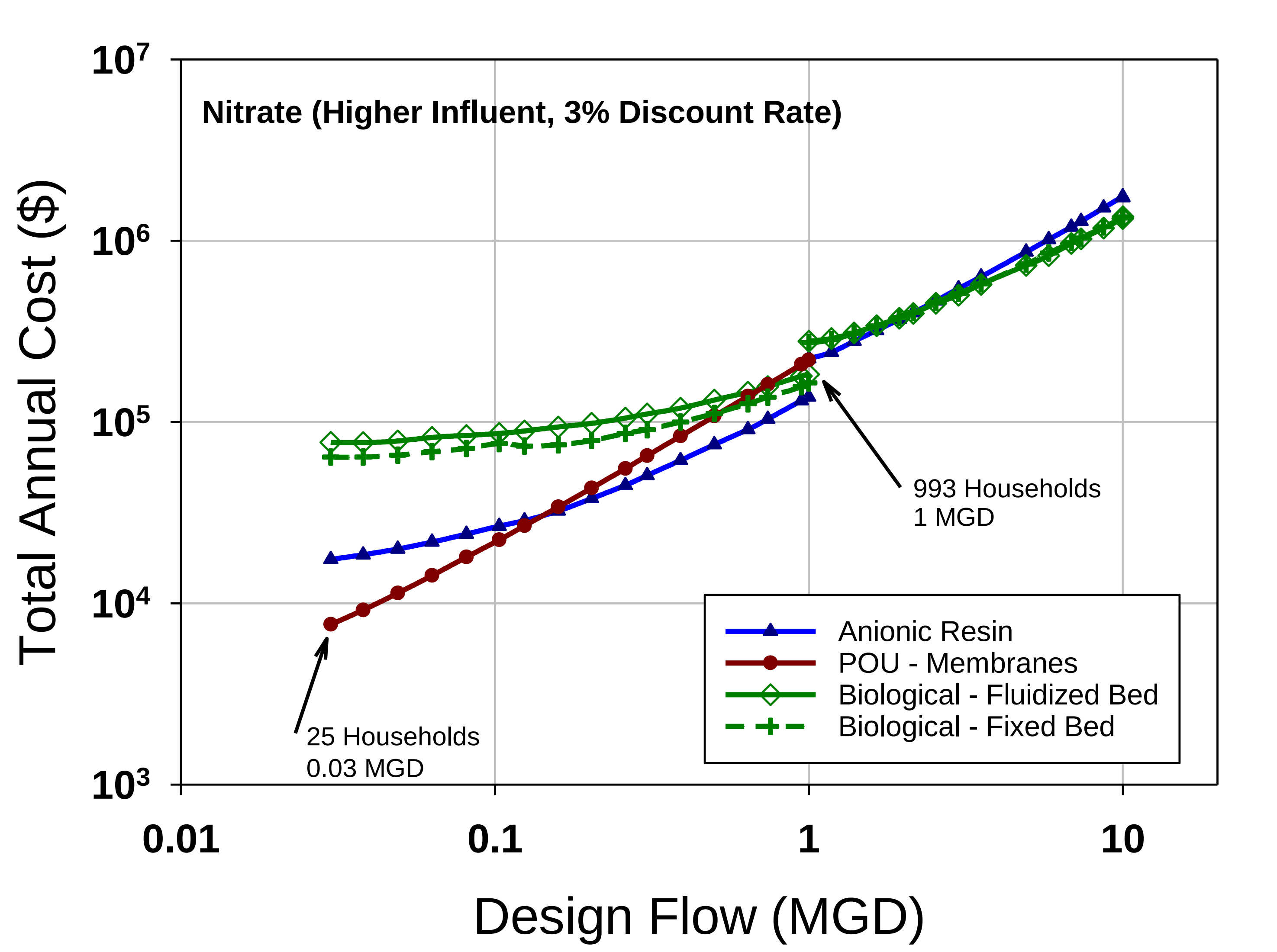
Cost: Nitrate (combined)



Primary Assumptions:

- Influent 44 mg N/L
- Groundwater
- Low cost option
- IEX: Nitrate selective
- Biological: Fluidized bed
- POU: Reverse Osmosis
- 7% Discount rate

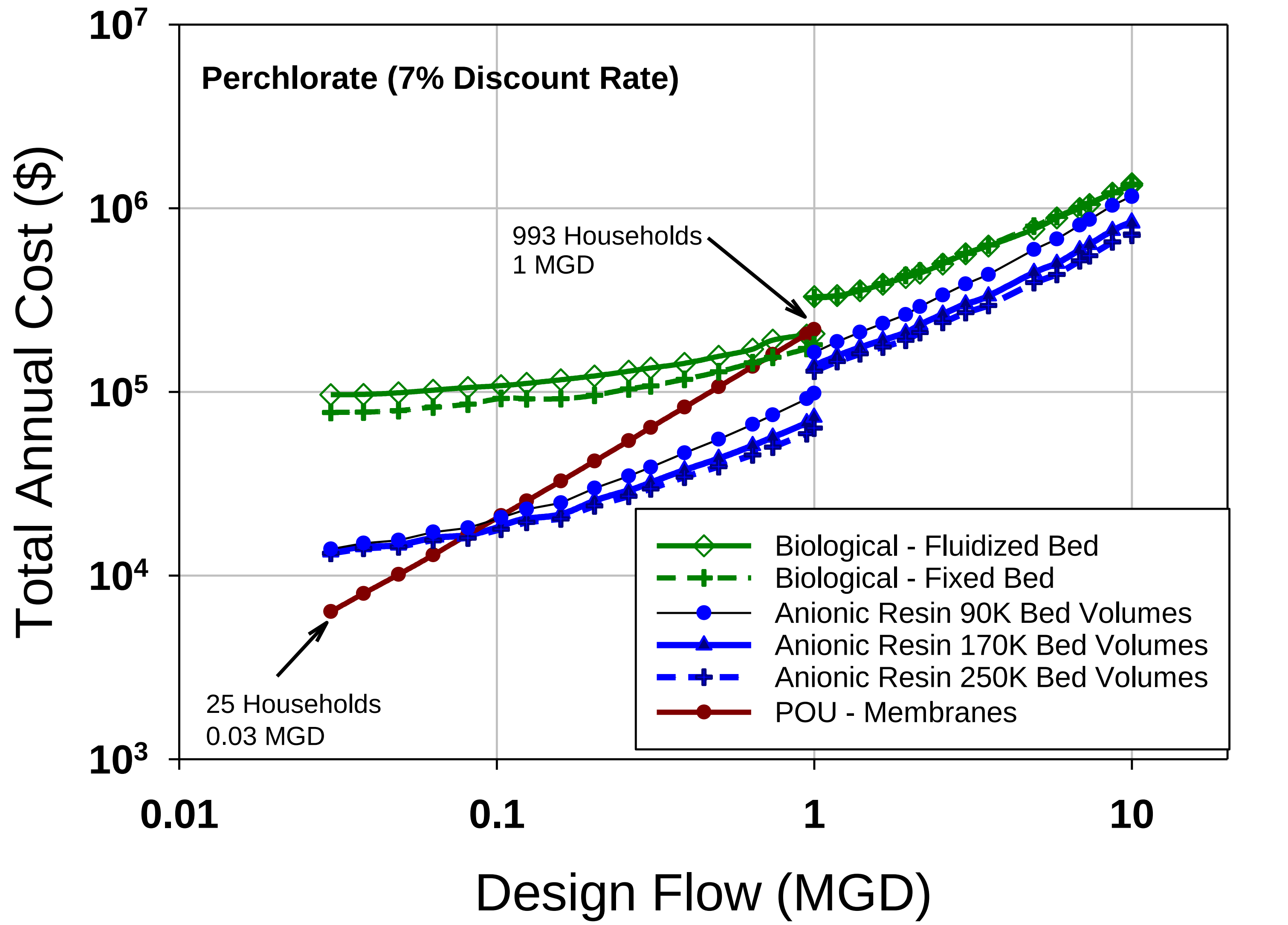
Cost: Nitrate (combined)



Primary Assumptions:

- Influent 44 mg N/L
- Groundwater
- Low cost option
- IEX: Nitrate selective
- Biological: Fluidized bed and Fixed bed
- POU: Reverse Osmosis
- 3 % Discount rate

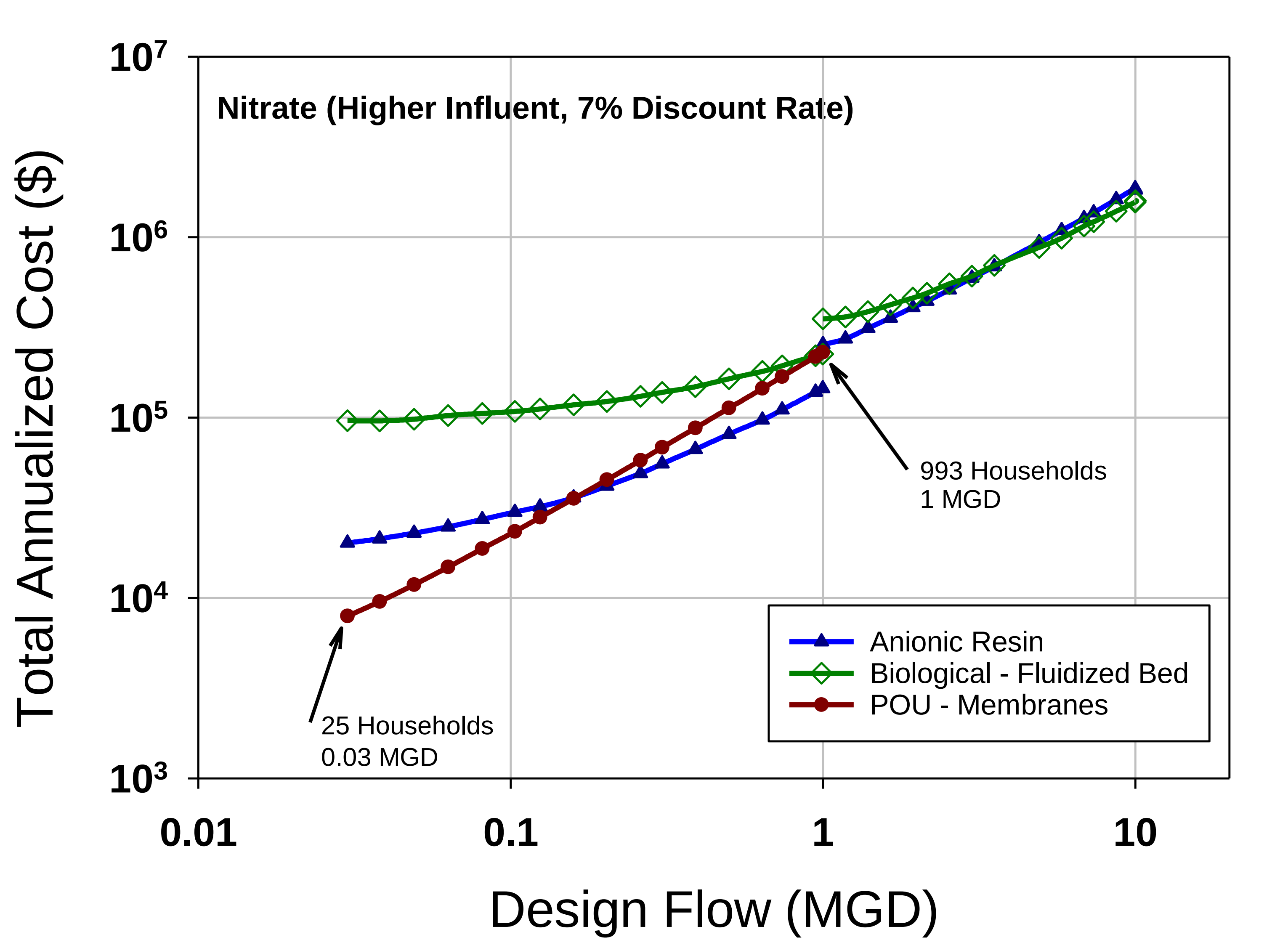
Cost: Perchlorate (combined)



Primary Assumptions:

- Influents: 24 – 270 ug/L
- Groundwater
- Low cost option
- IEX: Perchlorate selective
- Biological: Fluidized & fixed bed
- POU: Reverse Osmosis
- 7 % Discount rate

Cost: Nitrate (combined)



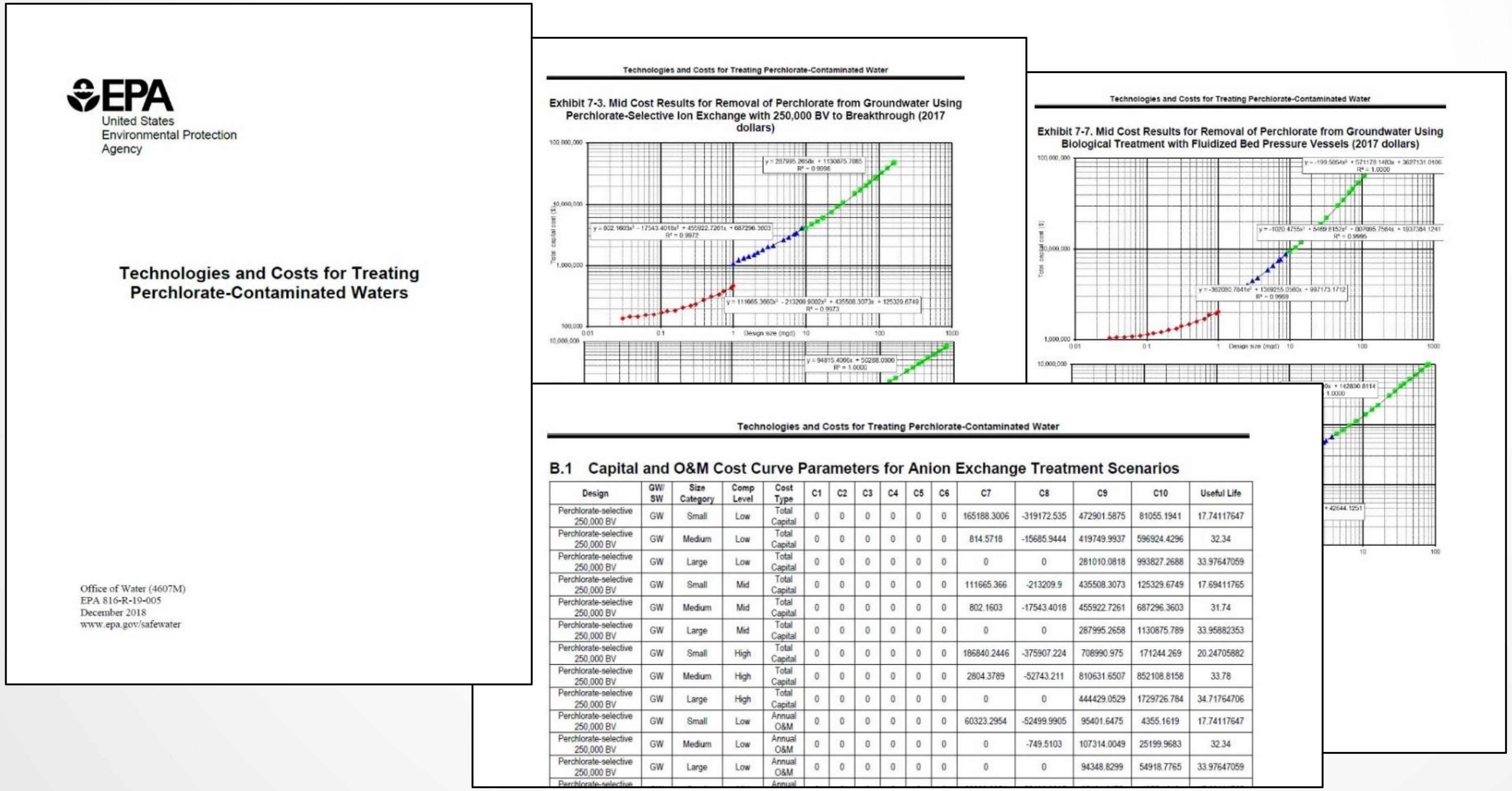
Primary Assumptions:

- Influent 44 mg N/L
- Groundwater
- IEX: Nitrate selective
- Biological: Fluidized & fixed bed
- POU: Reverse Osmosis
- 7% Discount rate

Perchlorate Technologies and Cost Document

Federal proposal (Supporting material): T&C document posted on Jun 26, 2019

- https://www.regulations.gov/document?D=EPA-HQ-OW-2018-0780-0002



Small System Compliance Technologies

For small systems, EPA identified several compliance technologies as affordable using the following approach:

- Estimated annualized costs for three size categories (using EPA's work breakdown structure models, which estimate the capital and operating costs for model systems)
- Compared annualized costs to an expenditure margin equal to 2.5% of median household income minus average annual baseline household water utility costs
- Identified SSCTs where annualized costs < expenditure margin

SSCT's for Perchlorate

Summary of results in Federal proposal that show Small System Compliance Technologies (SSCTs) by system size

System Size (Population Served)	Ion Exchange	Biological Treatment	Reverse Osmosis	Point-of-Use Reverse Osmosis
25-500	**$378 to $610**	*$2,146 to $3,709*	*$2,272 to $2,671*	**$265 to $271**
501-3,300	**$98 to $148**	**$324 to $566**	**$561 to $688**	**$250 to $251**
3,301-10,000	**$104 to $153**	**$211 to $315**	**$431 to $493**	*Not applicable*

Supporting material: SSCT Document posted on Jun 26, 2019
https://www.regulations.gov/document?D=EPA-HQ-OW-2018-0780-0111

Nitrate and Perchlorate Conclusions

- **Selective anion exchange resins** have the lowest costs for a wide range of systems sizes for both nitrate and perchlorate.
- For extremely small systems (below 200 homes), **point-of-use technologies (reverse osmosis)** have the lowest costs for both nitrate and perchlorate.
- For larger systems, **anoxic biological treatment systems** have the lowest costs, although for perchlorate, low concentrations and the high capacity of the selective resins favor ion exchange. Higher influent concentrations favor biological treatment.
- Note: Other conditions such as the presence of co-contaminants or counter ions will skew these costs and potentially move the choice to another technology.
- Note: Small systems often choose treatments based on other criteria such as operational complexity, residual stream management, facility limitations, etc..

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Per- and Polyfluoroalkyl Substances (PFAS)

1) Activated carbon
2) Anion exchange resin
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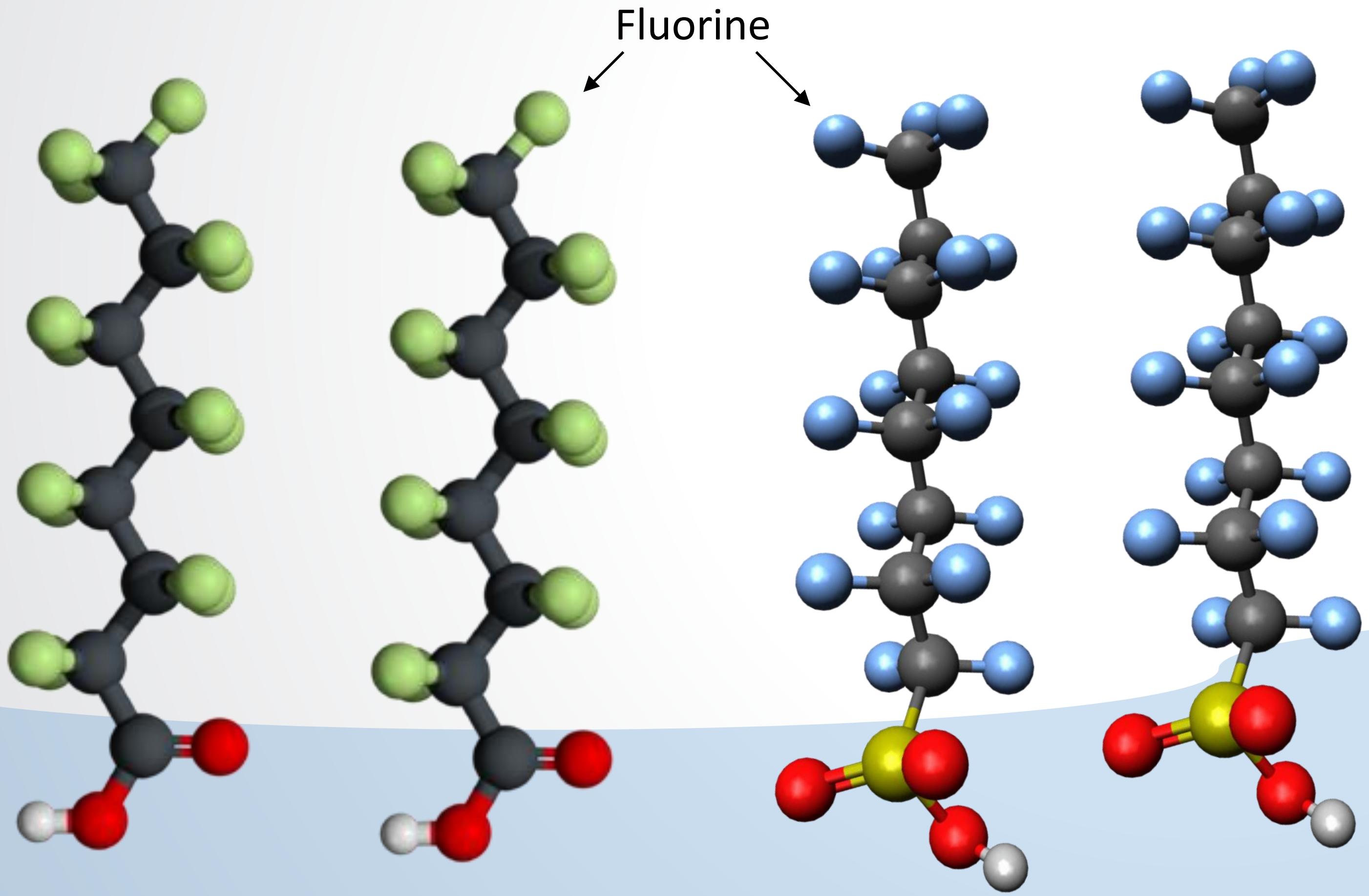
Per- and Polyfluoroalkyl Substances (PFAS)



Perfluorooctanoic acid (PFOA)

Perfluorooctanesulfonic acid (PFOS)

- **A class of chemicals**
  - Chains of carbon (C) atoms surrounded by fluorine (F) atoms
    - Water-repellent (hydrophobic body)
    - Stable C-F bond
  - Some PFAS include oxygen, hydrogen, sulfur and/or nitrogen atoms, creating a polar end

Drinking Water Treatment for PFOS

Ineffective Treatments

Conventional Treatment

Low Pressure Membranes

Biological Treatment (including slow sand filtration)

Disinfection

Oxidation

Advanced oxidation

PAC Dose to Achieve	
50% Removal	16 mg/l
90% Removal	>50 mg/L

Dudley et al., 2015

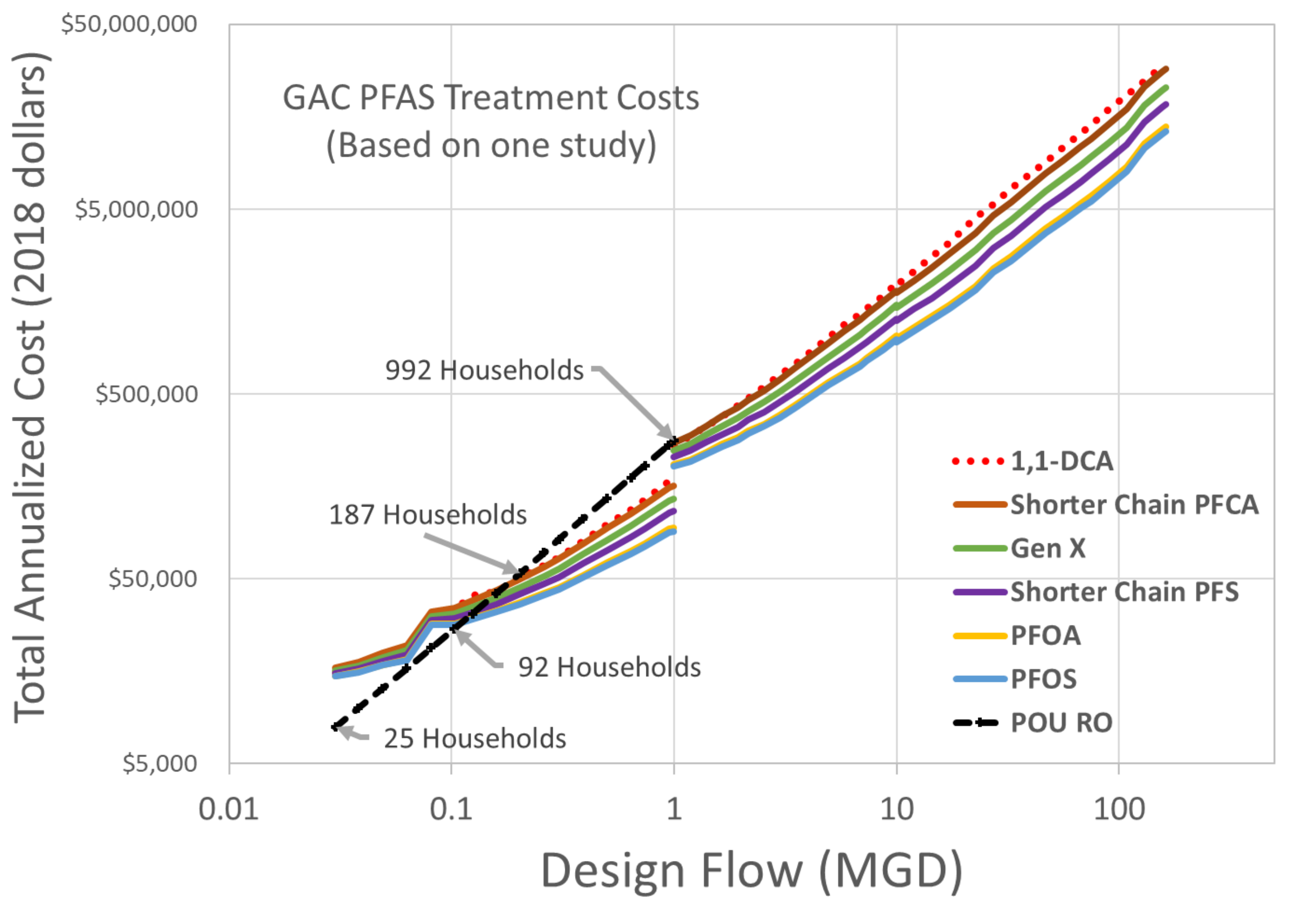
Effective Treatments

	Percent Removal	
Anion Exchange Resin (IEX)	90 to 99	- **Effective**
High Pressure Membranes	93 to 99	- **Effective**
Powdered Activated Carbon (PAC)	10 to 97	- **Effective for only select applications**
Granular Activated Carbon (GAC)		
Extended Run Time	0 to 26	- **Ineffective**
Designed for PFAS Removal	> 89 to > 98	- **Effective**

Costs for PFAS Treatment

- The POU devices that have gone through NSF/ANSI certification for PFOA and PFOS are all RO systems.
- The costs presented here use prices for devices that are certified under NSF 58, but not specifically for removal of PFOA and PFOS; however, we assume these prices are representative for devices certified specifically for PFOA and PFOS under NSF 58.
- The costs assume $250 per sample for laboratory analysis.
- Results are limited to less than 1 MGD (~1,000 households) based on assumption that only small systems would use POU programs.

Costs for PFAS Treatment: One GAC Example



Primary Assumptions:

- Two vessels in series
- 20 min EBCT Total
- Bed Volumes Fed

  1,1-DCA = 5,560 (7.5 min EBCT)

  Shorter Chain PFCA = 4,700

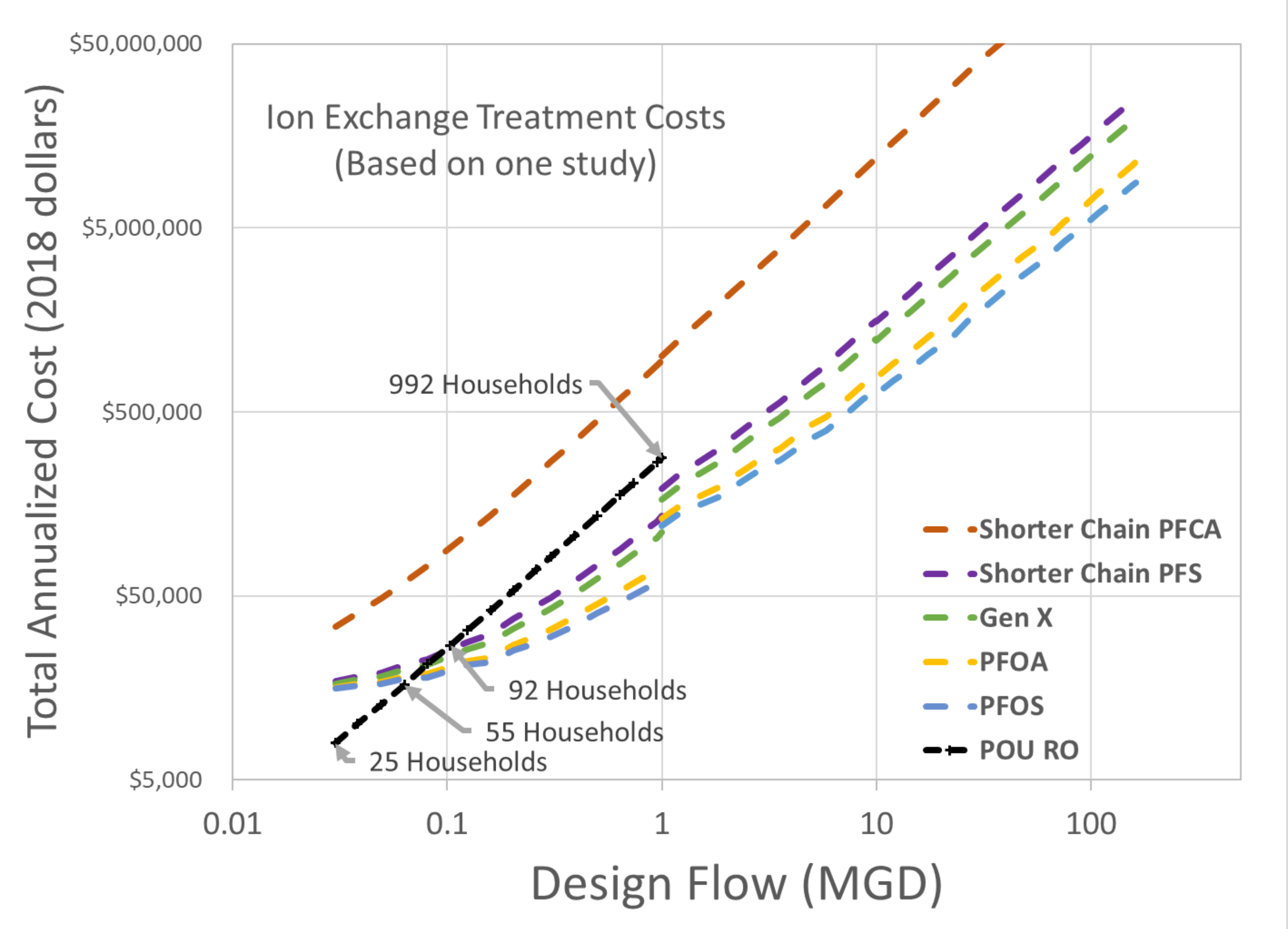
  Gen-X = 7,100

  Shorter Chain PFS = 11,400

  PFOA = 31,000

  PFOS = 45,000
- 7 % Discount rate
- Mid Level Cost

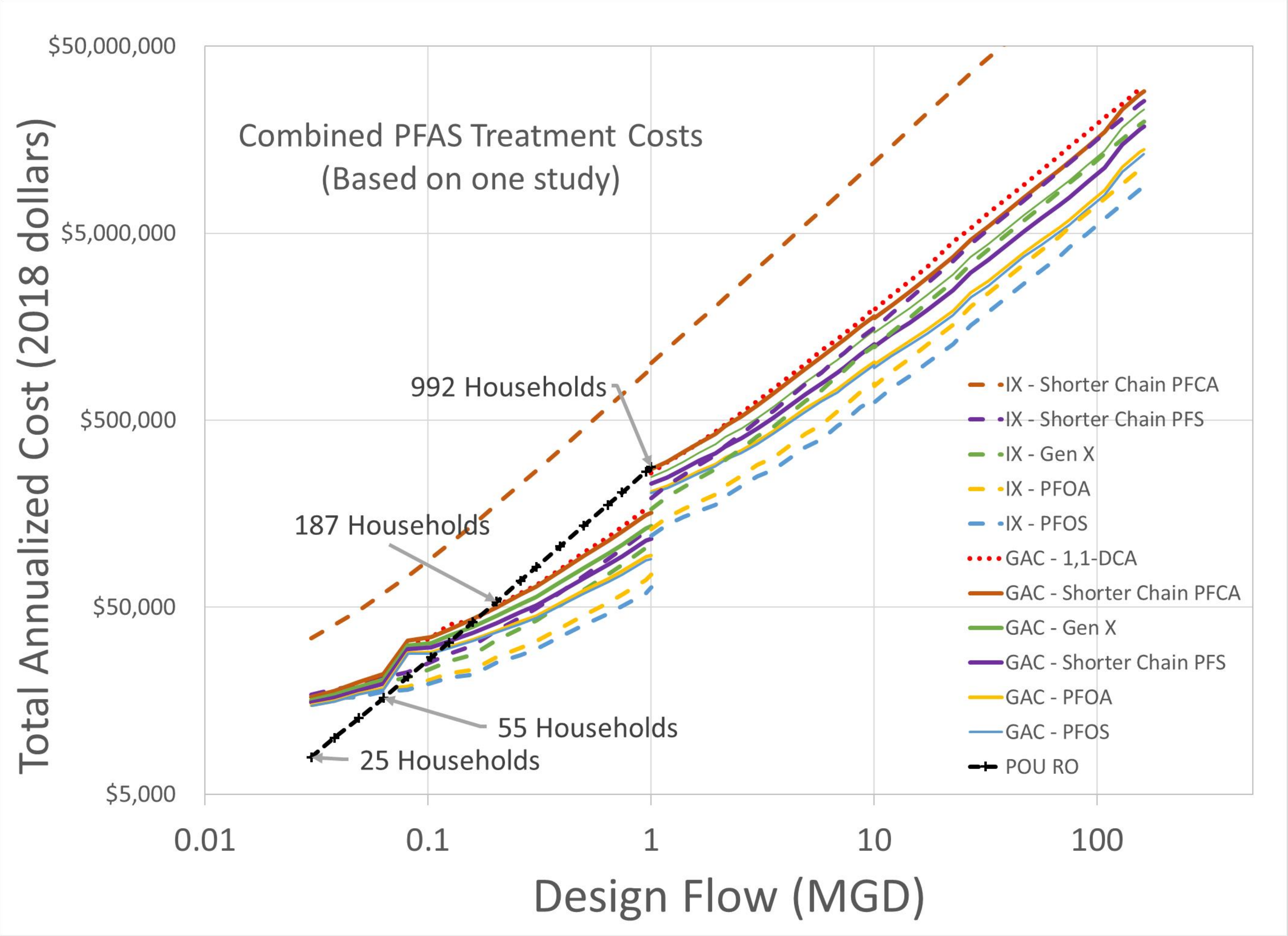
Costs for PFAS Treatment: One IEX Example



Primary Assumptions:

- Two vessels in series
- 3 min EBCT Total
- Bed Volumes Fed
  - Shorter Chain PFCA = 3,300
  - Gen-X = 47,600
  - Shorter Chain PFS = 34,125
  - PFOA = 112,500
  - PFOS = 191,100
- 7 % Discount rate
- Mid Level Cost

Costs for PFAS Treatment: One Example



Primary Assumptions:

- See previous two slides

PFAS Costing Conclusions

- Similar to nitrate and perchlorate, under certain conditions, POU devices can be the low-cost alternative to centralized treatment for PFAS although a state/utility will have to resolve other implementation concerns.
- In this instance, the cost of controlling PFAS by centralized GAC treatment is possible. Ion exchange is similar except for shorter chained PFCA, in this case.
- Although GAC showed many fewer bed volumes fed to breakthrough than ion exchange, the cost was similar to ion exchange treatment.
- Note: This exercise herein was based on one pilot study, data from additional sites will be needed for an exhaustive evaluation. Also, an evaluation at other relevant treatment goals and conditions is needed.

POU / POE Project Goal

To assess the PFAS removal using commercially available POU/POE Reverse Osmosis (RO) and Granular Activated Carbon (GAC) treatment systems simulating water from Colorado's Widefield Aquifer.

Point-of-Use (POU)
Kitchen sink, end-of-faucet, and pour-thru devices

Point-of-Entry (POE)
Whole House; typically installed in a hot water tank room or heated garage

Contact: Craig Patterson (Patterson.Craig@epa.gov)

Project Objectives

The project also documented:

- Ease of use during installation, startup, continuous and intermittent operation based on manufacturer instructions.

- Operation and maintenance schedules for replacement of RO units and GAC media based on manufacturer instructions.

Source: H2O Distributors

Reverse Osmosis Systems

POU/POE treatment tests on three RO systems (500-1000 gal/day)

- iSpring RCS5T (0.35 gpm)
- Hydrologic Evolution (0.7 gpm)
- Flexeon LP-700 (0.5 gpm)

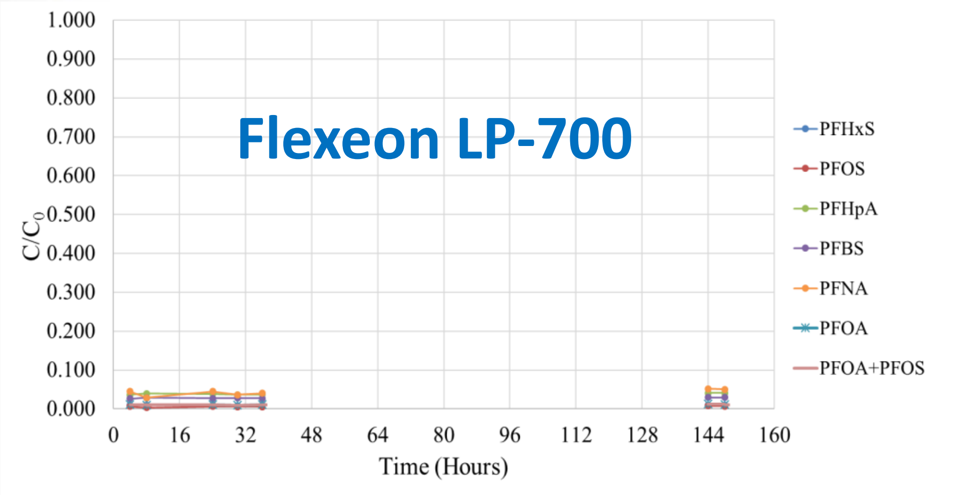
iSpring

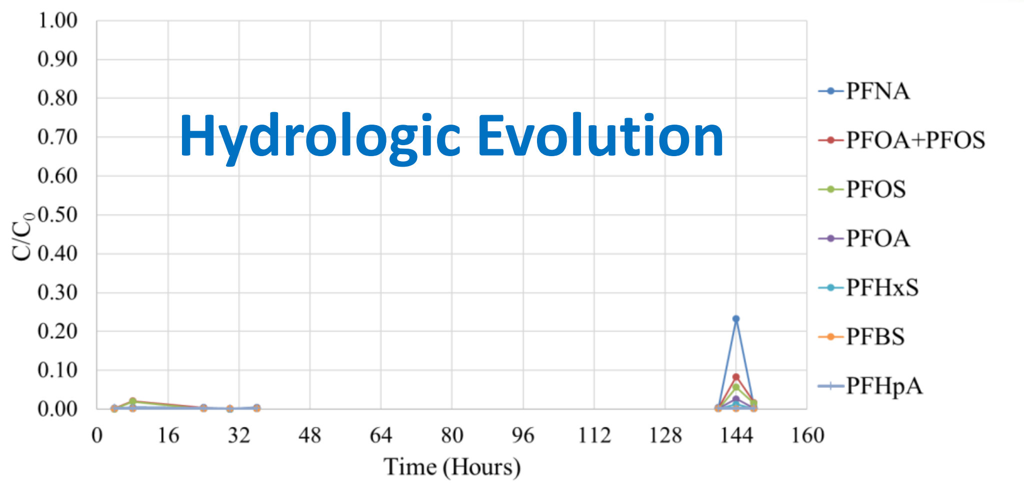
Hydrologic

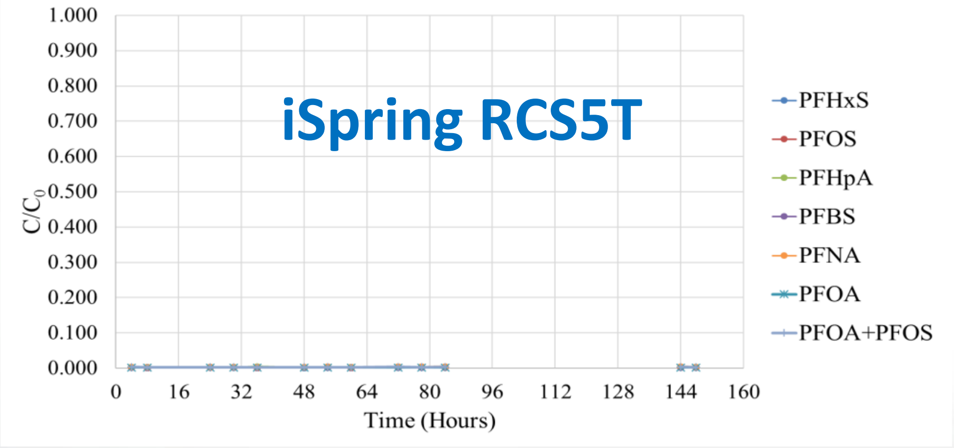
Flexeon

Sample Collection

PFAS Removal Membrane Studies



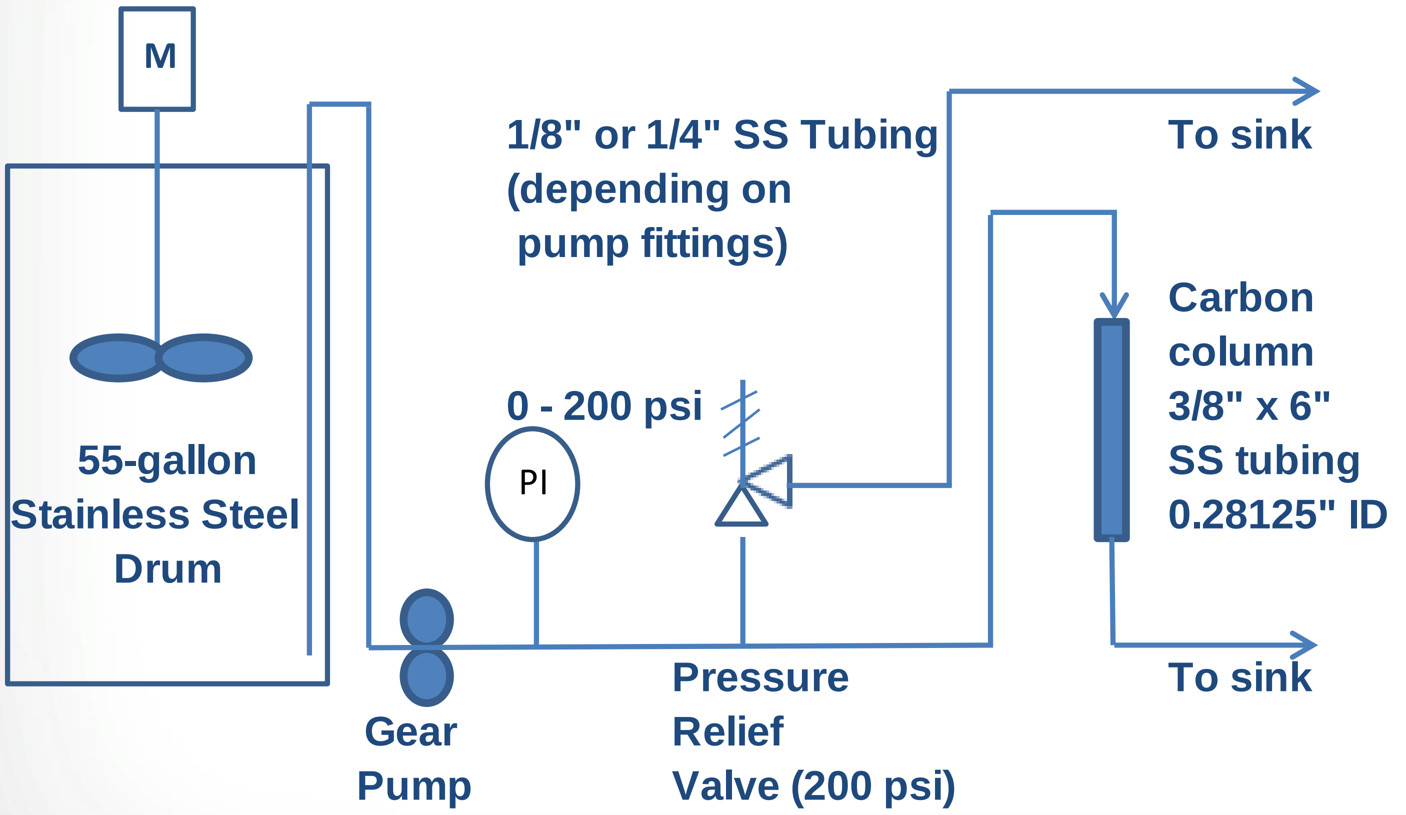




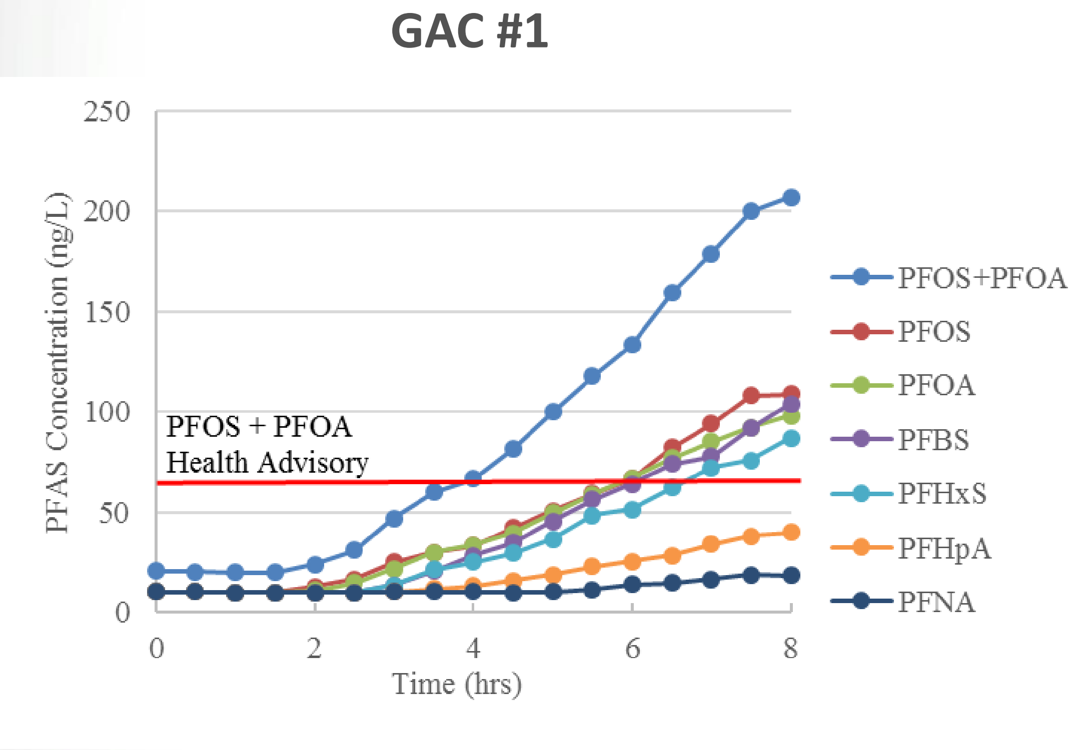
- **All three membranes showed excellent PFAS removal (only 6 of 42 PFAS results were greater than non-detect).**
- **Reason for re-start results for Hydrologic system was not determined.**

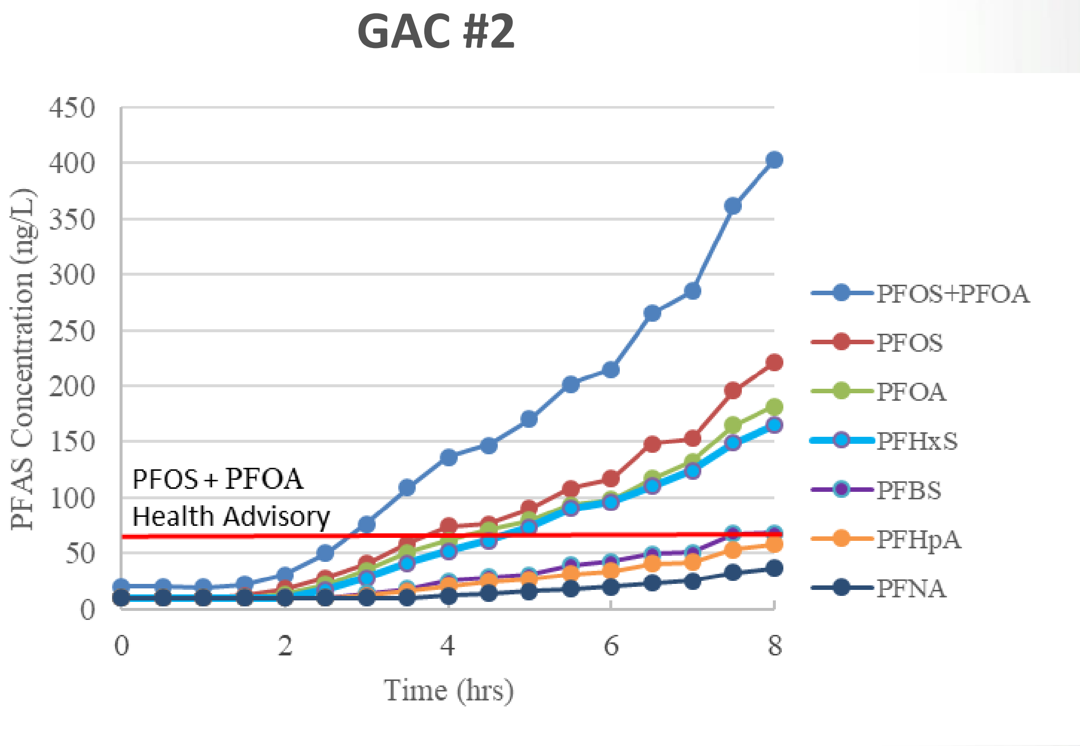
GAC RSSCT System

Rapid Small Scale Column Test (RSSCT)



RSSCT GAC Performance



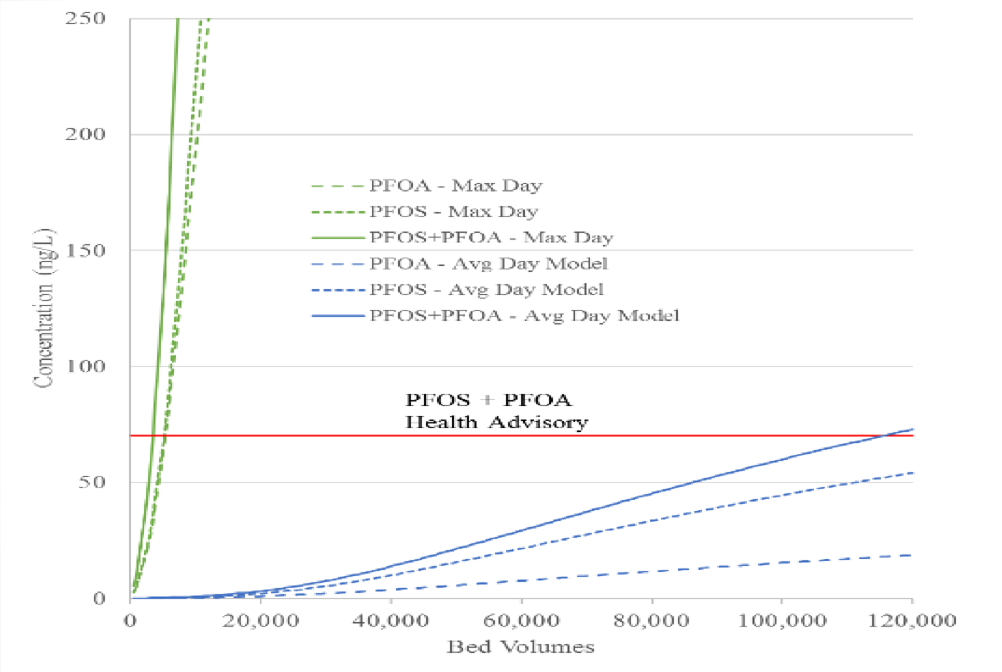


Similar breakthrough results for the two carbons

Predicted GAC Performance

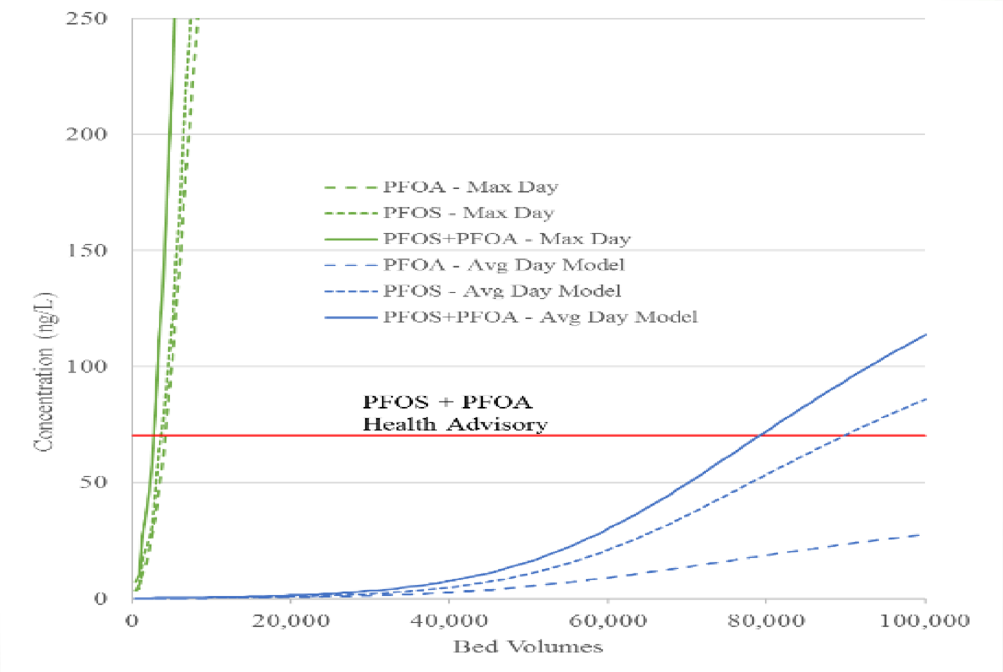
GAC #1

- Fit to Scaled RSSCT at (Max Day Conc): 3,400 BVs (24 days)
- Predicted Average Conc: 115,000 BVs (2.2 years)



GAC #2

- Fit to Scaled RSSCT (Max Day Conc): 2,700 BVs (19 days)
- Predicted Average Conc: 79,000 BVs (1.5 years)



Large Whole House Carbon Tanks Required for PFAS Removal (10 min EBCT each)

One 4-5 GPM Non-Backwashing Whole House Carbon Filter
$539
35"(H) x 9"(D) tank with 30 lbs (1 ft^3) of GAC (Source: H_2O Distributors)

Two Large Whole House Backwashing Carbon Filters
$3990
65"(H) x 16"(D) tank with 240 lbs (8 ft^3) of GAC (Source: H_2O Distributors)

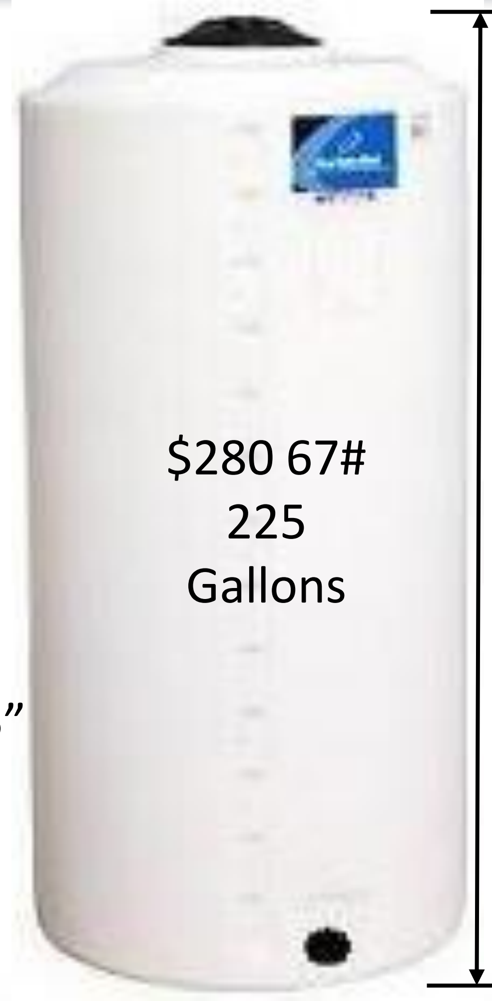
Small GAC System for PFAS Removal

Well Water Flow must be restricted to 0.5 gpm*

Requires at least a 4’x4’ Room

35”

9”



6’2”

31”

28”

25”

=

$1200 before installation, Weight: 200 lbs

*Requires more frequent GAC replacement

RO Modification for Point-of-Entry Use

RO = $500

RO Booster Pump = $880

$280 67#
225
Gallons

6’2”

31”

Requires at least a 4’x4’ Room
May require a re-mineralization cartridge

$36
064#

28”

25”

=

$2000 before installation,
Weight: 150 lbs

Requires Electricity for Well, RO Booster and Water Storage Tank Pumps

Household GAC and RO POE Systems

Granular Activated Carbon Systems	Reverse Osmosis System
Could experience contaminant breakthrough if the carbon change-out schedule is not followed. Frequent change out of smaller system GAC.	Unlikely to have contaminant breakthrough unless membrane has integrity issues.
May not be effective on short-chain PFAS	Treats many long- and short-chain PFAS
No residual stream except for spent media	Disposal of concentrate waste stream (20-50% of flow) may be an issue
No corrosion issues to deal with	Corrosion control in household plumbing may be an issue for point-of-entry water treatment
For large GAC system, cold water temperature not affected because of flow on demand – no holding tank. For small system, holding tank is required.	Like the small GAC system, holding tank is required. Residents may complain about room temperature “cold water”
Potential issues with logistics, cost, and safety of carbon replacement	Potential issues with sanitizing components and replacing cartridges & tubing on a regular basis

POU/POE Project Conclusions

- The three **RO systems** tested successfully removed PFAS to below analytical detection for a majority of the limited sampling events.
- For the **GAC systems**, modeling the results for lower, more relevant, concentrations gave bed lives of 1.5 and 2.2 years in this case.
- Therefore, for this water, the RO and GAC POU/POE water systems successfully removed the PFAS studied, and were relatively inexpensive.
- Each type of system had advantages and disadvantages that go beyond cost.
- Proper design, operation, maintenance, and conservative replacement of components and media is one way to reduce the monitoring requirements for the treatment of household drinking water.

Contact: Craig Patterson (Patterson.Craig@epa.gov)

Questions?

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